



Report of the

ACMRR/SCOR/ACOMR/GESAMP JOINT WORKING PARTY ON
GLOBAL INVESTIGATION OF POLLUTION IN THE MARINE ENVIRONMENT (GIPME)

San Marco di Castellabate and Rome, Italy
11—18 October 1971

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PREPARATION OF THIS REPORT

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PREFACE

The Group of Experts on Long-Term Scientific Policy and Planning established by the Intergovernmental Oceanographic Commission proposed in November 1970 that the Commission should establish a Global Investigation of Pollution in the Marine Environment (GIPME) as a major project in its Long-Term and Expanded Programme of Oceanic Exploration and Research (LEPOR). Subsequently the Bureau of the Commission at its meeting with the Consultative Council in Bordeaux in March 1971 requested the Commission's scientific advisory bodies (SCOR, ACMRR and ACOMR), together with GESAMP, to cooperate in developing the programme elements of this global investigation and to prepare a working paper for consideration at the Seventh Session of the Commission to be held in November 1971.

In response to this request, the advisory bodies and GESAMP agreed to establish a Joint Working Party on the Global Investigation of Pollution in the Marine Environment with the following terms of reference:

1. To review relevant documents concerning programmes of scientific investigation of pollution in the marine environment.
2. To identify the lines of research that appear to be the most effective in such investigations.
3. To develop an outline for GIPME, including estimates of priorities and timing and of the facilities and manpower required, and to suggest institutional arrangements for the planning and coordination of the work and the allocation of responsibilities for parts of the programme among the various interested organizations.
4. To note the regional approach to the development of GIPME suggested by GESAMP and to (a) consider areas, additional to those named by GESAMP, in which investigations might be commenced at an early date, (b) bear in mind the need to enable the developing nations to take an active part in GIPME.

This group met at San Marco di Castellabate, Italy, from 11 to 16 October and in Rome on 18 October 1971. A list of the participants is given in Annex I. Mr. A.J. Lee was appointed Chairman and Professor W.S. Wooster acted as Rapporteur. Excellent arrangements were provided by FAO and enabled the group to conduct its work expeditiously.

SUMMARY OF RECOMMENDATIONS

In considering the great variety of research efforts that will ultimately be required to answer the questions raised by man's increasing pollution of the ocean, the Working Group decided to identify a number of projects that should be initiated now. Some of these require elaboration by appropriate specialists, while others are ready for action by international organizations. Implementation of the proposals below, with the coordination of IOC, would compose the initial phase of GIPME.

The following recommendations were agreed:

1. That SCOR and ACOMR, in collaboration with the Commission on Atmospheric Chemistry and Radioactivity (of IAMAP) evaluate the problems involved in studying the transport of pollutants through the atmosphere and their transfer to the ocean, including the development of suitable sampling methods, and consider means for promoting their investigation, with the goal of achieving the capability of conducting a multiship observational programme by 1974.
2. That IOC consider the desirability and method of organizing an international multidisciplinary study of River Inputs to Ocean Systems (RIOS) and that as an initial step the IOC Secretariat compile an inventory of present national and international programmes of river discharge study and measurement, including the monitoring of river-borne pollutants.
3. That SCOR, in cooperation with other interested scientific groups, examine the possibility of designing critical experiments to evaluate the rate and extent of vertical transfer of materials across the thermocline by physical and biological processes.
4. That SCOR and ACMRR, in cooperation with other interested scientific groups, evaluate further the concept and design of a comprehensive investigation into the dynamics of ecosystems in relation to pollution, identify the methodological problems, and propose programmes for its implementation.
5. That GESAMP consider how best to promote the international exchange of information on research into the survival and fate of pathogenic bacteria and viruses in the marine environment.
6. That SCOPE, in cooperation with SCOR and ACMRR, be invited to arrange for consultation, coordination and information exchange on studies of pollutant concentrations in natural deposits and in marine and other organisms held in museum and other collections, paying particular attention to possible contamination and changes in composition with preservation and storage.
7. That ACMRR elicit, evaluate and disseminate information on biological accumulators of pollutants and encourage their use in monitoring programmes.
8. That a joint SCOR-ACMRR working group be established to review the various aspects of design and methodology in monitoring the biological effects of pollutants, to evaluate the research required to perfect methods for application in monitoring programmes, and to recommend ways whereby this research can be expedited through international cooperation.
9. That IOC encourage and coordinate national and regional programmes for marine pollution present state (base line) studies, giving due attention to the improvement and intercalibration of analytical methods and training in their use, and the exchange and evaluation of data and other results and information.
10. That IOC arrange now for scientists engaged in national and regional studies on present levels and/or effects of marine pollution to combine their findings in a preliminary report on the "health of the ocean".

11. That GESAMP (1) propose initial criteria to be met from the point of view of the marine environment in establishing test programmes for evaluation of product toxicity, and (2) in consultation with ICES and other appropriate bodies, prepare an initial list of biological criteria to be satisfied before approvals for ocean dumping should be issued.
12. That IOC promote the organization of networks of cooperating laboratories concerned with marine problems, on regional and subject bases, for the exchange of information, improvement and intercalibration of methods, provision of analytical services, and coordination of scientific effort, training and education. Regional networks should be developed within the context of regional cooperative investigations and regional organizations where these exist. In the case of subject networks, high priority should be given to (a) laboratories concerned with determining the effects of pollutants on marine organisms, and (b) laboratories concerned with development and application of methods for determining chemical pollutants in sea water, marine organisms and sediments.
13. That IOC in the first place explore the possibility of developing in a suitable location an International Institute of Tropical Oceanography whose functions would include education and training, and marine research. The research effort should include present-state baseline studies of marine pollutants and related problems. It could also include the study of structure and process characteristic of coral reefs and lagoons, and of mangrove associations. Eventually, several laboratories of this character may be required.

INTRODUCTORY REMARKS

The unfolding pattern of ocean pollution is the product of three factors that derive from the fecundity, the acquisitiveness and the inventiveness of man. Human populations are growing. More energy and bulk materials are consumed per person. The rate of technical innovation is increasing.

These statements have been made often recently, and therefore may seem to be clichés. They are not. Solutions to the problems raised by these factors are no less imperative just because the problems themselves have been exposed. No-one concerned with human welfare can put these fundamental problems aside, no matter what his special interest and competence. Marine pollution research identifies consequences of these problems as far as the ocean is concerned and indicates ways to control and correct deleterious consequences. Therefore the expansion of marine pollution research must be related to the expansion of the fundamental problems.

Given the present human age structure and mortality trends, and assuming virtually immediate and drastic control of birth rates, the population is expected to triple early in the next century. More realistic estimates are of five-fold increases, or more.

The rate of release of energy and the movement of materials per person is growing exponentially. This rate of increase may be slowed or even stabilized eventually as key resources become scarcer. But to slow it significantly will require major changes in social attitude. We must expect that it will at least double by early next century.

It seems certain that biologically-active substances of a great variety will be invented, manufactured, and some of them introduced into the environment at a vastly accelerated pace. In the past decade we have come to worry about a handful of such synthetics. In the next decade or so we shall surely be conscious of the effects of considerable numbers of them. Two trends will further intensify the pollution of the marine environment. Human populations and industries are accelerating their movement to coastal zones. The pressure of pollution on land and freshwater resources is leading to the disposal of wastes into the ocean at increasing rates.

The general pollution problem, and therefore marine pollution problems, may become ten to one hundred times more serious during the lifetime of our children. That is not to say that there will be necessarily that much more pollution in the sea. Controls are likely to be applied to some of the contributing factors. But long-term planning calls for very much greater efforts in research and control than are now being made.

We cannot expect to quantify or synthesize all of the trends in pollution because of the changes in speed and consistency of society's response. There is already response. For example, the revised draft treaty on ocean dumping envisages that dumping toxic wastes into the sea would be severely restricted, and permitted only if such dumping causes little harm. Conclusion of any such treaty will make new demands on marine research programmes to evaluate the dangers and alternatives. Probably the manufacture and use of biologically active substances will be restrained increasingly by requirements for prior testing to determine whether the risks to human health, living resources and the environment are acceptable. To accomplish this, marine scientists will need complex tests in physiology, ecology and behaviour with a large number of compounds. Along with the vast growth in transport of hazardous cargoes efforts to increase safety are intensifying, but accidents are inevitable. They may be fewer but bigger and more varied. The consequences of this must be anticipated.

Investigations proposed in this report must help us to deal with current problems and at the same time prepare us for more and bigger future ones. We should concentrate on the major and continuing problems. Rigorous studies of the sources, pathways and effects of DDT and PCBs will show us how to study many other active substances. Through the regional study of polluted areas such as the North Sea, the Mediterranean and the Baltic Sea, we shall learn how to make effective studies elsewhere. In establishing standardized methods and modest monitoring arrangements we shall lay the foundation for a more comprehensive system.

At the same time, work on long-term problems must be started now. We must do baseline studies of the present levels and distribution of certain pollutants and of the composition and structure of selected biological communities. We must identify the fundamental processes which determine the pathways and ecological effects of introduced substances. By one kind of investigation, we seek to detect changes; by the other, to predict consequences.

In our proposals for GIPME we seek both short and longer term objectives, in the light of present knowledge and anticipated trends; to recognize both regional and global problems, and to sharpen our methods. The nature of our problem is determined more by what man does on land than by what he does at sea, and hence it is closely related to vaster environmental problems, but nevertheless research on marine pollution is an integral part of marine science - oceanography in its broadest sense - which has its own methods and its special characteristic international flavour.

PROPOSALS TO THE COMMISSION

(i) The Scope of GIPME

(a) Categories of pollution problems

Marine pollution problems can be regarded as falling into two categories:

..... Those that are concerned with direct effects to human health, amenities, fisheries and other marine activities;

..... Those that are concerned with ecological, and hence more indirect effects, which may eventually result in harm to living resources and hazards to man.

In geographical terms they can be sub-divided into those of the coastal zone, the shelf seas, and the open ocean.

The problems of the coastal zones usually apply to small localized areas under national jurisdiction and related to hazards to human health, reduction of amenities, and damage to local fisheries. However, some coastal zones form the nursery grounds of stocks of commercial species of fish which are exploited by a number of nations. The pollution of these zones is therefore of international concern. Further, the scientific aspects of coastal problems throughout the world have a number of common features, and solutions in particular cases may be obtained more quickly if there is international exchange of information and ideas.

In shelf seas and virtually enclosed seas (e.g. the Mediterranean) the problems are of a regional character and are best attacked by the coordination of the activities of the countries around those seas, particularly as some coastal problems must also be taken into account. They again relate to some extent to hazards to human health and to the reduction of amenities, but the major concern is possible damage to fish stocks which are exploited by a number of nations and so it is essential to study ecological effects.

The problems of the open ocean are primarily concerned with these ecological and largely indirect, but none the less important, effects. They are global in extent and cannot be studied without consideration of the role of the atmosphere as a source of pollutants or of the problems of the shelf seas which flank the oceans. The attack of them has to be made on the widest possible basis.

GIPME should therefore (i) provide the initiative for the study of the pollution of the open ocean; (ii) have a coordinating function which facilitates and draws upon regional studies such as those at present going on in the North Sea, the Mediterranean and the Baltic Sea and in the North Atlantic; (iii) act as a clearing house for information yielded by studies carried out on a national basis but of international interest.

(b) Types of pollutants

Other groups of workers have listed the pollutants of most concern and described their effects. We have seen no need to repeat the latter here but agree that at the present time attention should be paid within GIPME to the study of the heavy metals (mercury, cadmium, lead, zinc, and others), the chlorinated aromatic hydrocarbons (DDT, PCBs and others), the halogenated hydrocarbons in general (the aliphatic hydrocarbon wastes from PVC manufacture and others), petroleum, microbiological pollution (sewage disposal) and artificial radioactivity (plutonium and some of the activation products). The importance of a pollutant varies from area to area and we have not therefore attempted any form of ranking. We consider that the impact of petroleum, especially crude oil, on the marine environment may have been over-estimated, but nevertheless regard it as highly desirable that studies should be made of the degradation of crude oil and that the toxic components of crude oil should be identified.

(c) Types of study

Marine pollution problems, no matter whether they are in coastal zone, the shelf seas, or the open ocean, require for each pollutant a study of:

- (a) Its sources and rate of input;
- (b) Its dispersal and transport by physical processes and its transformation by chemical processes;
- (c) Its transfer and transformation by biological processes;
- (d) Its effects on marine organisms;
- (e) Its fate on the marine environment.

We have considered these various topics and in doing so have made extensive use of the reports of a number of groups who have also studied them, as well as other aspects of the marine pollution problem. A list of the reports available to us is given in Annex II and we wish to acknowledge to the authors our debt of gratitude for the considerable help that their reports have given us in our deliberations. These reports contain a number of useful recommendations concerning specific studies in the marine pollution field. We do not consider it necessary to list them all again but we wish to encourage work along the lines proposed. Instead we have attempted to provide below a list of several projects which we consider to be essential for the development of GIPME in its initial stages.

We wish to endorse the findings of other groups that the study of the marine pollution problem would be made much easier if (a) international and national arrangements could be made to produce world production figures for a number of substances, (b) qualitative and quantitative information were made available on domestic sewage and industrial waste discharges to the sea from outfalls, from rivers, and from dumping. In this way the rates of input of wastes and the mass balance for certain substances could be determined.

(d) The multidisciplinary approach

We consider that GIPME requires a multidisciplinary approach. This can be seen by taking as an example the study of the input of pollutants to the ocean. The most rapid dispersion of pollutants to the sea occurs through the atmosphere. Wind transport of materials leads to a comparatively uniform blanket coverage of the world oceans along the path of the wind systems. The uniform distribution of pollutants transported by the atmosphere is only generally true for gases and vapours, i.e. those substances that do not get washed out by rain. Even with these substances, there is more deposition near continents, but it is of the same magnitude as in the deep seas. However, with particulate materials and aerosols, there is only a relatively uniform distribution in an east-west direction. There is a major deposition in the temperate zonal wind systems, with sharp cutoff at the tropics, judging by radioactive fallout data. It is generally considered that those materials which are transported by the wind systems can lead to global problems if they are persistent. This is the case with chlorinated hydrocarbons and could arise with mercury and lead.

Coastal injections of wastes occur through outfalls, rivers, and coastal runoff. These inputs are affected normally by the various characteristics which prevail in the nearshore environment. Estuarine conditions lead to a variety of alterations in a pollutant's characteristics and in its behaviour. For example, a silt-laden river will cause some of the pollutant constituents to be abstracted from the water during the process of flocculation and sedimentation of the silt. Moreover, biological activity

can strongly influence materials introduced into coastal waters, both in quantity and quality. It is generally considered that only a fraction of waste passes to the open sea through the filtering process of the coastal zone's biogeochemical activity.

The services of biologists, chemists, physicists, geologists, meteorologists, mathematicians and engineers are clearly needed if the problems raised by these inputs are to be studied in detail.

(e) Surveys and Experimental Studies

Considerable attention is at present being devoted to the question of monitoring the ocean in order to establish the degree of pollution present. We have studied the various proposals made by different groups (see Annex II) and have concluded that the study of marine pollution has two aspects:

- (i) The conduct of surveys in order to determine the state of the marine ecosystem and its environment in relation to pollution;
- (ii) The conduct of laboratory and field experiments in order to study how the marine ecosystem functions, and how it responds to changes such as the introduction of a pollutant.

With regard to (i), such surveys are required now in order to determine the present state. They are essentially chemical surveys to show the amounts of certain pollutants present in the various parts of the ecosystem and its environment and how they are being transferred and transformed. These surveys are baseline surveys and we regard them as applying to the situation now, but as being conducted over the next one or two years in order to smooth out any seasonal fluctuations, etc. They should be repeated at intervals in order to identify any changes that may occur.

Such baseline surveys will be expensive to carry out and will require careful planning. The analytical procedures for a number of critical organic compounds and for certain metals are very sophisticated. International co-ordination of research work on analytical methods is required, together with tests to ensure that the data obtained by different laboratories are comparable. Even the most advanced laboratories find some of this work both difficult and expensive. The mounting of marine pollution studies in the developing countries thus poses particular problems requiring special attention by the world community with regard to highly specialized training and funding for the purchasing of expensive equipment.

The two lines of study given above interact with each other in two ways. The design of a surveillance system should be based on the results of appropriate scientific investigations. On the other hand, data produced by that system can be used in scientific research. The early phases of developing the system are largely of an investigatory nature: by the time it is established as a service the role of scientists is largely in quality control and in evaluation of the resulting data.

The nature of a monitoring system must derive from its purpose. The Intergovernmental Working Group on Monitoring or Surveillance (Geneva, 1971) defined monitoring as "a system of continual observation, measurement and evaluation for defined purposes." If it has an "early warning" character, to keep track of the concentrations of certain substances so that controls can be applied when a determined value is about to be exceeded, then only by research can we determine which levels can be permitted. When a predictive model for the effects of a pollutant has been formulated, the results of monitoring can be introduced and a prediction of consequences obtained.

One can measure either the concentrations of various pollutants in sea water, organisms and sediments, or the effects of pollutants on organisms, either as individuals, or collectively. Most programmes of continuing observations at present in progress or in the planning phase measure concentrations of pollutants rather than their effects, mainly because methodology for the latter is usually not available. The abundance and species composition of marine communities are highly variable, the process linking them is highly complex, and the most suitable means for describing and investigating these communities remain to be determined. In the same way that the productivity index is a more stable parameter than primary production or chlorophyll concentration, so species composition or growth rates of selected organisms may be more stable parameters than abundance. The large variance in time series of biological data calls for better experimental design and methods of analysis: a method of signal enhancement is needed before a useful model can be erected and more effective monitoring introduced.

The question of selecting the most suitable test organisms for monitoring also remains to be solved. Proposals range from zooplankton to yearling seals. Decisions should be based on the purpose of monitoring and the model on which it is based.

Present understanding tells us that an ecosystem, whether of a small community or of the whole biosphere, comprises a complex of closely inter-related processes, in which the environment of any one organism is the sum total of the influence of other organisms, together with that of the physical and chemical elements in the system on which their life intimately depends. Man is one of these organisms and he is part of the environment of each of the others.

It is characteristic of such systems that their elements are continually changing, in some respects slowly but at times dramatically, and in some ways regularly but in others irregularly. There is no doubt that all these changes have their effects, short or long-term, on other elements in the system. But ecology is a relatively recent and poorly supported science, despite its significance for man, and we are still very ignorant of many of the processes involved.

This is true of even the systems on land, particularly those that are influenced by the rapidly increasing impact of man's activities: we have even less access to those in the sea. Yet it is these we must be most careful to safeguard.

Although the carrying capacity of the seas is vast by comparison with those of lakes and rivers, if it should ever be approached, the problem of retrieving the situation will be vast if not quite impossible. Yet the scientific effort available today is inadequate for accurate prediction of the consequences of pollution even on its present scale. As a result, our present monitoring is elementary and at times ill-conceived.

If the predictions instanced in the introductory section are correct (and there is no reason whatever to doubt them), then not only is a more intensive monitoring and evaluating system required, but a much more intensive and far-reaching investigation of the underlying processes will be needed than has so far been foreseen. It is essential that the effort devoted to increased understanding should not be sacrificed for the monitoring effort, essential though this is, if the results from the latter are to justify the effort and give ample warning of dangers that lie ahead.

Perhaps the essence of the problem may be illustrated by an over-simplified example in relation to man. The pollutants being released into the rivers and seas may have short-term dangers for him, for example, when he eats an excessive load of toxin over a short period or even once. Alternatively, he may become progressively weakened, and even die through the more prolonged consumption of marine foods bearing a much smaller load of toxin that accumulates in his own tissues. Another type of danger he runs is less immediate - that of his food supply being reduced due to an environment that is poisoned, though at levels which may not directly harm man himself. Perhaps a more likely possibility is that in which the living marine resources used by man are endangered because of the vulnerability of their own food supply to one or more toxins. With each step into the system we can see how the effects of a pollutant can be transmitted, and begin to realize how, in fact, the pathways and processes are much more complex than may at first be supposed.

Thus, we must apply the information and understanding available at any one moment to the ad hoc problems presented by the state of pollution at that moment, and our monitoring must be designed on this basis. If we are to be prepared for the inevitably increasing tempo of pollution, at least for some time, it seems essential that we do not merely wait until each new pollutant is revealed, but that we make a concentrated attack on problems of the ecosystem in order to elucidate at least some of the principal relationships and effects. In this way only can we ensure that a model will be available to permit relatively short-term evaluation of the introduction of any new pollutant.

For this reason there is emphasis in our recommendations, not only on baseline (present state) surveys, but also on a broadly planned ecological approach, which, in turn, will quickly yield better information with which to redesign our monitoring. The ecological and experimental studies, on the one hand, and monitoring on the other, are complementary.

(ii) Recommendations concerning projects

I. ATMOSPHERIC TRANSPORT OF POLLUTANTS

Considering the importance of air-borne transport of pollutants, surprisingly little is known about the concentration of substances thus transported, how and where they enter the sea, nor what happens to them immediately after entering the sea. Such information is needed particularly in the case of heavy metals, halogenated hydrocarbons, and petroleum.

Some substances, like dust and aerosols, are carried down and can be measured in rainfall; others, like gases and vapours, are taken up at the sea surface by molecular impact. In the latter case, the concentration of pollutant in air must be measured as well as the uptake coefficient for each substance (a surface film of oil will affect this coefficient).

It must be recognized that adequate methods are not now available for the study of these problems. There is no suitable technique for the routine collection of large uncontaminated samples of rain water on ships. There is some experience in the pumping and filtering of large volumes of air, but further work is required to ensure freedom from contamination and to enhance extraction and concentration. Perfection of the methods might benefit from the assistance of chemical engineers; design of a suitable observational programme will require the joint efforts of meteorologists and oceanographers.

When suitable methods have been developed, their use should be encouraged, first on individual vessels, and later on multiship programmes, such as the GARP Atlantic Tropical Experiment (GATE) scheduled for 1974. A goal for the study of atmospheric transport of pollutants could be to perfect the methods and design an observational programme for incorporation in GATE in 1974.

We recommend that SCOR and ACOMR in collaboration with the Commission on Atmospheric Chemistry and Radioactivity (of IAMAP) evaluate the problems involved in studying the transport of pollutants through the atmosphere and their transfer to the ocean, including the development of suitable sampling methods, and consider means for promoting their investigation, with the goal of achieving the capability of conducting a multiship observational programme by 1974.

II. RIVER INPUTS TO OCEAN SYSTEMS

Rivers carry important amounts of pollutants to the ocean. These pollutants may be dissolved or particulate and may be precipitated as sediments upon reaching the sea or taken up rapidly by organisms present. Some rivers are important because of their large volume discharge, others because of their large pollutant load.

The volume discharges of many rivers are commonly monitored by national hydrological services. Such monitoring is to some extent integrated internationally, for example in the International Hydrological Decade. In recent years, the discharges of some rivers have been monitored for certain pollutants, although these programmes are not extensive nor are they integrated with parallel programmes of marine pollution monitoring. It should be noted that such integration will require relating the different methodologies of hydrology and oceanography.

It seems appropriate at this time to consider development of a coordinated multidisciplinary study of river discharges into the ocean, for the purposes of evaluating their role in introducing pollutants and of understanding the nature of their influence on the biology, geology (see GELTSPAP Geoscience Exercise 4.4) and physical oceanography of the nearshore regime. Such a programme might be designated River Inputs to Ocean Systems (RIOS).

We recommend that IOC consider the desirability and method of organizing an international multidisciplinary study of River Inputs to Ocean Systems (RIOS) and that as an initial step the IOC Secretariat compile an inventory of present national and international programmes of river discharge study and measurement, including the monitoring of river-borne pollutants.

III. MIXING AND DIFFUSION

Rapid horizontal distribution of pollutants across the ocean is achieved by the winds. Once these materials have penetrated the surface, evidence from studies of radioactive materials suggests that vertical mixing is rapid through the layer above the thermocline; lateral transport by physical processes in the water is slow compared to the speed of atmospheric transport.

The incidence of offshore dumping of toxic substances, and the development of offshore exploitation of mineral resources, leads in the first instance to the need for understanding of vertical exchange between deep water and the surface waters, layers that are commonly separated by the thermocline. Biological transport by vertically migrating organisms may play a significant role in transferring pollutants across this barrier.

Several international investigations now being planned, such as the ICES Overflow Experiment, the Geochemical Sections (GEOSECS) programme of IDOE, and the Mid Ocean Dynamics Experiment (MODE) being developed by SCOR, may give some information on the rate of vertical exchange by physical processes. Some understanding of biological transfer may result from the ECOS investigation (see Proposal IV). However, none of these investigations is specifically designed to yield information on the consequences of introducing pollutants well below the thermocline.

We recommend that SCOR, in cooperation with other interested scientific groups, examine the possibility of designing critical experiments to evaluate the rate and extent of vertical transfer of materials across the thermocline by physical and biological processes.

IV. DYNAMICS OF ECOSYSTEMS IN RELATION TO POLLUTION

Ultimately, the understanding of how pollutants are transferred and transformed by marine organisms, and the ability to predict the consequences of these interactions, will derive from advances in knowledge of the dynamics of marine ecosystems. These advances will come from a combination of observation in the natural environment, experimental work in the laboratory, and modelling. As discussed earlier in the report, and in the conclusions of the IBP/PM Working Conference (Rome, 1971) it now seems desirable to stimulate this work by considering the development of detailed biological investigations of comprehensive character at a few critical sites. These investigations would require measurements of the rates of transport of both pollutants and organic matter through major parts of a system, a breakdown of this picture into smaller components such as trophic levels or particular species, and investigation of the homeostatic or controlling factors which maintain the system in the face of environmental fluctuations (see Annex IV).

The overall complex of investigations might be carried out first at a temperate continental shelf location, but should later be done at sites on a comparable tropical shelf, and in the open ocean. Design of the observational programme should be guided by appropriate models which in turn can be improved by the field results and by the results of laboratory experiments.

We recommend that SCOR and ACMRR in cooperation with other interested scientific groups, evaluate further the concept and design of a comprehensive investigation into the dynamics of ecosystems in relation to pollution, identify the methodological problems, and propose programmes for its implementation.

V. PATHOGENIC BACTERIA AND VIRUSES

Pathogenic bacterial and viruses reach the ocean in domestic sewage through rivers and outfalls. They present a direct threat to human health and to living resources. Little is known about these pathogens, especially the viruses, in the sea. Knowledge is being only slowly acquired, in part because the research efforts of marine and health scientists have different objectives.

As a first step to expedite these investigations, we recommend that GESAMP consider how best to promote the international exchange of information on research into the survival and fate of pathogenic bacteria and viruses in the marine environment.

VI. RETROSPECTIVE MONITORING

In assessing the impact of man's effluents on the marine environment, useful information can be obtained from analyses of historical materials. In part, these records have been retained in nature, notably in glaciers and in varved sediments. The study of such materials reveals the long-term characteristics of some natural fluctuations; the upper layers of varved sediments may also reveal the effect of recent inputs of man.

Historical collections of marine organisms may permit reconstruction of the incidence and rate of accumulation of substances introduced by man, (e.g. mercury in fish and birds). Plankton collected several decades ago are available for analysis, although little work of this sort has yet been undertaken. Appropriate methods remain to be developed, and the effect of storage conditions and procedures on the content of pollutants remains to be established.

We recommend that SCOPE, in cooperation with SCOR and ACMRR, be invited to arrange for consultation, coordination and information exchange on studies of pollutant concentrations in natural deposits and in marine and other organisms held in museum and other collections, paying particular attention to possible contamination and changes in composition with preservation and storage.

VII. BIOLOGICAL ACCUMULATORS OF POLLUTANTS

In developing methods for monitoring pollution in the marine environment, particular attention should be paid to the selection of organisms that can facilitate the task. Such organisms may concentrate pollutants or integrate their distributions in useful ways. For example:

1. Plankton samples could be collected in a standardized fashion from research vessels and ships of opportunity in many parts of the world ocean and analyzed for pollutants, leading to a picture of the distribution of contamination on an ocean-wide basis.
2. Bivalve molluscs detect and store persistent pollutants present at very low concentrations, either in solution or adsorbed on particulate matter. This capability could be used by attaching containers of appropriate oysters or mussels to oceanic buoys, weather ships and other offshore platforms, for periodic removal and analysis.
3. Seals collect annually at known rookeries. Chemical analysis of appropriate tissues will yield a composite picture of the dietary intake of pollutants along the migration pathways of the preceding year.
4. Salmon and eels spend specific parts of their life cycle in the ocean and can be sampled on their return to estuarine waters. Their behaviour as juveniles, sub-adults and mature fish make it possible to evaluate the dietary intake of pollutants during known periods of time, and often for known regions of the ocean.

In all these cases, representative portions of the samples should be retained for later re-examination when more sensitive analytical methods become available or when additional important pollutants have been identified.

We recommend that ACMRR elicit, evaluate and disseminate information on biological accumulators of pollutants and encourage their use in monitoring programmes.

VIII. MONITORING BIOLOGICAL EFFECTS

In general, pollution monitoring involves the systematic measurement of quantities of various substances believed or known to have harmful effects. A weakness of this approach is that one cannot anticipate which of a very large number of potential pollutants, some of which do not yet exist, should be watched. It is essential also to monitor the effects of pollutants on organisms and their populations and communities. Methods for monitoring biological effects in the ocean are not yet well developed; several entrées to the problem are suggested:

1. The interpretation of biological monitoring data involves the methods of time-series analysis. The problem is to distinguish changes caused by pollution from the background of variability characteristic of biological systems. A few time series of marine biological data and collections are available (e.g., plankton recorder surveys in the North Sea and North Atlantic, routine plankton samples from the California Current) and should be subjected to appropriate time-series analysis to explore the scales and frequencies of variation in the records. The results of such a study would contribute to the design of effective biological monitoring programmes.
2. Data from the plankton recorder surveys in the North Sea and North Atlantic indicate long-term changes in zooplankton standing stocks and communities. Appropriate experiments should be performed to test the possible effects of pollutants in causing the observed changes in certain species. Such experimental work is a necessary part of biological monitoring programmes.
3. The presence or abundance in a habitat of certain species can indicate the presence and effects of particular pollutants. Regional registries of carefully evaluated indicator species should be compiled for use by those involved in monitoring programmes.

4. Pollution affects the structure of biological communities. Certain mathematical formulations of productivity, diversity, and stability have been proposed as useful indices of these effects. The interpretation and application of these indices requires careful evaluation.
5. Communities of bottom-dwelling animals often show more obvious response to pollution than do open water communities and can more clearly indicate the gradient and distribution of pollution. Further studies of the effects of various pollutants on benthic communities are desirable.

We recommend the establishment of a joint SCOR - ACMRR working group to review the various aspects of design and methodology in monitoring the biological effects of pollutants, to evaluate the research required to perfect methods for application in monitoring programmes, and to recommend ways whereby this research can be expedited through international cooperation.

IX. PRESENT STATE (BASELINE) STUDIES

Studies of the present distribution of pollutants in sea water, marine organisms and sediments are known as baseline studies and constitute the initial phase of pollution monitoring. During this phase, the necessary methods are developed and applied, experience is gained in the making of observations that may later be incorporated into a monitoring system, and an initial appreciation of the nature and magnitude of marine pollution is acquired.

Such studies are already underway or are being organized, notably in the North Sea and the Baltic Sea under the leadership of ICES, in the North Atlantic and Pacific as part of the International Decade of Ocean Exploration, in the Mediterranean as part of the Cooperative Investigation of the Mediterranean (CIM) and in the Western Pacific by Japan Meteorological Agency. It is essential that the results and experience of these preliminary studies be evaluated and that similar studies be developed in other regions including Arctic and tropical regions so that a more comprehensive picture of the present state of marine pollution can be obtained.

We recommend that IOC encourage and coordinate national and regional programmes for marine pollution present state (baseline) studies, giving due attention to the improvement and intercalibration of analytical methods and training in their use, and the exchange and evaluation of data and other results and information.

X. HEALTH OF THE OCEAN

Earlier proposals have been made for periodic reports on the sources, distribution and movement of the main pollutants in the marine environment and organisms. Such reports on the "health of the ocean" would result from the synthesis and evaluation of the results of environmental monitoring. Studies are now underway in several regions to assess the present concentrations and distributions of certain pollutants. Compilation of the results of these studies would provide an initial assessment of the condition of the ocean while illustrating the need for closer coordination of such efforts and improved intercomparability of methods.

We recommend that IOC arrange now for scientists engaged in national and regional studies on present levels and/or effects of marine pollution to combine their findings in a preliminary report on the "health of the ocean".

XI. PRODUCT TOXICITY AND DUMPING

Product Toxicity: Increased understanding of ecological relationships and a growing sense of public responsibility are leading to acceptance of the concept that manufacturers contributing to pollution of the environment must demonstrate the relative non-toxicity of their product before it can be released to the environment. Short-term toxicity tests are not sufficient, since experience has shown the importance of effects, such as those on behaviour and physiology, resulting from longer exposures to low concentrations. In the case of products that can eventually reach the ocean, it is important that the effects on marine organisms and ecosystems be established.

Ocean Dumping: The ocean has long been used as a convenient receptacle for wastes. With the rapid increase of population in coastal areas, this practice is tending to increase exponentially, and there is already evidence of ecological disruptions in some regions. It is gratifying that some steps are now being taken by governments to control ocean dumping, yet it seems inevitable that economic and other considerations will result in some materials continuing to be dumped. In such

cases, it is essential that the dumper demonstrate the effects of his actions on marine life. To do so will require detailed information on the nature of the materials being dumped and their effect on marine organisms, and on the environment and communities and populations of organisms at the dumping site. An adequate list of criteria to be satisfied by those proposing to deposit wastes in the ocean has yet to be established.

We recommend that GESAMP (1) propose initial criteria to be met from the point of view of the marine environment in establishing test programmes for evaluation of product toxicity, and (2) in consultation with ICES and other appropriate bodies, prepare an initial list of biological criteria to be satisfied before approvals for ocean dumping should be issued.

XII. LABORATORIES AND LABORATORY NETWORKS

Research is underway at a number of laboratories, particularly in the developed countries, on problems related to marine pollution, including the development and application of methods for determining chemical pollutants in sea water, marine organisms and sediments, and the determination of effects of pollutants on organisms. These laboratories are the elements of scientific effort from which GIPME will be composed.

Already in some regions laboratories are closely associated in their activities. For example, in the North Sea and Baltic Sea, marine laboratories are effectively linked through ICES. There are also rudimentary networks, sometimes of temporary nature, for specific problems and projects. Now urgent problems of improving analytical methods and of determining pollution effects require that such networks be more effectively established and supported. Regional pollution study centres should be included in such networks where appropriate.

We recommend that IOC promote the organization of networks of cooperating laboratories concerned with marine problems, on regional and subject bases, for the exchange of information, improvement and intercalibration of methods, provision of analytical services and coordination of scientific effort, training and education. Regional networks should be developed within the context of regional cooperative investigations and regional organizations where these exist. In the case of subject networks, high priority should be given to (a) laboratories concerned with determining the effects of pollutants on marine organisms, and (b) laboratories concerned with development and application of methods for determining chemical pollutants in sea water, marine organisms and sediments.

In the developing world, there are few laboratories where studies of marine pollution are being undertaken. This makes it particularly difficult to carry out baseline and other pollution studies in tropical regions where the present condition of the marine environment is little known and the biological effects and processes of transformation are poorly understood. To investigate effectively pollution in the tropical oceans, it is necessary to assist countries and laboratories in such regions to develop the capability of participating in the investigation of marine environmental problems. This capability will also be useful in the development and management of living marine resources.

We recommend that IOC in the first place explore the possibility of developing in a suitable location an International Institute of Tropical Oceanography whose functions would include education and training, and marine research. The research effort should include present state baseline studies of marine pollutants and related problems. It could also include the study of structures and processes characteristic of coral reefs and lagoons, and of mangrove associations. Eventually, several laboratories of this character may be required.

(iii) Institutional Arrangements

- (a) A basic assumption was that GIPME, as a part of LEPOR, is a programme of international cooperation being developed and coordinated by the Intergovernmental Oceanographic Commission, with the help of the supporting UN agencies associated in ICSPRO whose several programmes it may serve to coordinate, and of its advisory bodies (at present, SCOR, ACMRR and ACOMR). Thus, when we refer to "IOC" in the report, we mean both the IOC itself and the complex of organizations through which its actions are supported or implemented. By the same token, when reference is made to one of the advisory bodies, this is intended to draw on the complex of bodies with which it normally collaborates.
- (b) As in the past there is no doubt about the willingness of the advisory or associate bodies to assist IOC to the best of their ability. Hitherto, it has proved possible for the advisory bodies to fund the subsistence and travel expenses required for the operation in working parties established to provide advice for IOC. However, if assistance is sought of the kind envisaged in these recommendations, then it will be necessary for IOC to find the funds required.
- (c) Lastly, if adopted, it will be necessary to provide arrangements for organizing and coordinating GIPME within the framework of the IOC. It is not clear at this stage how this can best be achieved, in part because IOC is at present re-organizing its committee structure. It appears that a system of IOC Standing Committees might eventually emerge.

Should this be the case, then the coordinating body for GIPME might report to one of these. The following possibilities might be considered.

- (i) A joint organizing group consisting of appropriate governmental and non-governmental representatives. (Such a committee would be analogous to the Joint Organizing Committee for GARP);
- (ii) A group consisting of representatives of laboratories carrying out the various projects included in GIPME, as is a practice of ICES.

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1/ The Working Group consisted of members nominated by SCOR (Lee, Mourlon, Seki), ACMRR (Berge, Butler, Steele), ACOMR (Münnich) and GESAMP (Keckes), together with officers of those bodies and representatives of SCOPE and the UN Specialized Agencies

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List of Documents

Working Papers

- GIPME/71/WP. 1 Terms of Reference of GIPME. Extract from the Report of the Sixth Session of ACMRR. Rome, March 1971
- WP. 2 List of Working Papers
- WP. 3 List of Information Papers
- WP. 4 List of Participants
- WP. 5 Report of the FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing. Rome, 9-18 December 1970
- WP. 6 Group of Experts on Long-Term Scientific Policy and Planning (GELTSPAP). - Report of the First Session, Monaco, 16-25 November 1970
- WP. 7 Comprehensive Outline of the Scope of the Long-Term and Expanded Programme of Oceanic Exploration and Research. IOC, Technical Series No. 7
- WP. 8 IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP). Report of the Third Session, Rome 22-27 February 1971
- WP. 9 Report of the Seminar on Methods of Detection, Measurement and Monitoring of Pollutants in the Marine Environment, Rome 4-10 December 1970
- WP. 10 UN Conference on the Human Environment/Inter-Governmental Working Group on Marine Pollution. Report of the First Session, London 14-18 June 1971
- WP. 11 UN Conference on the Human Environment/Inter-Governmental Working Group on Monitoring and Surveillance. Report of the First Session, Geneva 16-20 August 1971
- WP. 12 International Council for the Exploration of the Sea. Papers submitted at the 59th Session, Helsinki 27 September-1 October 1971:
- C.M. 1971/E:37 The ad hoc ICES/SCOR Meeting to consider the possibilities for an international investigation of the pollution of the Baltic
- C.M. 1971/E:25 ICES Working Group on Pollution of the North Sea. Questionnaire to determine Sources of Input to the North Sea
- C.M. 1971/Gen:2 Progress Report on Some Important Activities of the Council or where the Council is Engaged (Extract)
- WP. 13 Outline for the Design of an Integrated Marine Pollution Monitoring System (K. Grasshoff)
- WP. 14 Global Investigation of Pollution in the Marine Environment. A synthesis of concepts from selected documents (G. Smith)
- WP. 15 Proposal for Pesticide Monitoring in the Mediterranean Sea (N.C. Hulings)
- WP. 16 Pollution Monitoring: An Engineering Challenge (J.M. Snodgrass)
- WP. 17 International Study of the Pollution of the North Sea and its Effects on Living Resources and their Exploitation (A.J. Lee)

GIPME/71/WP. 18 Draft Report of GIPME

WP. 18 Rev. 1 Revised Draft Report

WP. 19 Ecological Problems in the Study of Marine Pollution (J.H. Steele, Chairman of a GIPME ad hoc discussion group on Ecological Problems)

WP. 20 Rates and Methods of Introduction of Pollutants and Physical and Chemical Processes Moving Them Through the Marine Environment (M. Waldichuk, Chairman of a GIPME ad hoc discussion group on Physical and Chemical Processes)

Information Papers

GIPME/71/IP. 1 Chlorinated Hydrocarbons in the Marine Environment. National Academy of Sciences Washington, D.C., 1971

IP. 2 Principles for Limiting the Introduction of Radioactive Waste into the Sea. IAEA, Vienna 1970

IP. 3 Comments on Technical Capabilities for Monitoring Water Quality made to the Sub-Committee on Air and Water Pollution of the Senate Committee on Public Works - May 1970

IP. 4 Report of the Sixth Session of the Advisory Committee on Marine Resources Research - Rome 1971

IP. 5 Global Monitoring of Atmospheric Pollution and its Possible Relation to a Global Marine Monitoring Scheme (E. Eriksson). Paper submitted to the FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing - Rome 1970

IP. 6 Automation of Monitoring Equipment for Marine Pollution Studies (R.D. Gafford). Paper presented to the FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing - Rome 1970

IP. 7 Plankton in the North Atlantic - An Example of the Problems of Analyzing Variability in the Environment (R.S. Glover et al.). Paper presented to the FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing - Rome 1970

IP. 8 Monitoring of Creeping Over-Fertilization in the Baltic (I. Haahtela). Paper presented to the FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing - Rome 1970

IP. 9 Constitutional and Financial Arrangements required by the Commission to Promote the Development of Cooperative Scientific and Scientific Support Activities in Marine Pollution (IOC Circular Letter No. 354)

IP. 10 International Biological Programme. Working Conference, FAO, Rome 4-8 October 1971. Selected documents

IP. 11 Introduction and General Position Statement (Founder Council Engineering Committee on Oceanic Resources)

IP. 12 Remarks on Pollution and its Monitoring (J. Isaacs, S. Fonselius)

IP. 13 Programme for Monitoring Pollution of the Marine Environment (Japan Meteorological Agency)

List of Abbreviations

ACMRR	Advisory Committee on Marine Resources Research
ACOMR	Advisory Committee on Oceanic Meteorological Research, WMO
CACGP	Commission on Atmospheric Chemistry and Global Pollution
FAO	Food and Agriculture Organization of the United Nations
GARP	Global Atmospheric Research Programme
GATE	GARP Atlantic Tropical Experiment
GELTSPAP	Group of Experts on Long-Term Scientific Policy and Planning (IOC)
GESAMP	IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN Joint Group of Experts on the Scientific Aspects of Marine Pollution
GIPME	Global Investigation of Pollution in the Marine Environment
GEOSECS	Geochemical Ocean Section Study
IAMAP	International Association of Meteorology and Atmospheric Physics
ICES	International Council for the Exploration of the Sea
ICSPRO	Inter-Secretariat Committee on Scientific Programmes Relating to Oceanography
ICSU	International Council of Scientific Unions
IDOE	International Decade of Ocean Exploration
IHD	International Hydrological Decade
IOC	Intergovernmental Oceanographic Commission
LEPOR	Long-term and Expanded Programme of Oceanic Exploration and Research
MODE	Mid-Ocean Dynamics Experiment
SCOPE	Scientific Committee on Problems of the Environment (ICSU)
SCOR	Scientific Committee on Oceanic Research (ICSU)
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHO	World Health Organization
WMO	World Meteorological Organization

ECOLOGICAL PROBLEMS IN THE STUDY OF MARINE POLLUTION

by

J.H. STEELE

Chairman, GIPME ad hoc discussion group on Ecological Problems

A Programme for Future Work

The programme required can be divided into three stages:

- (1) Measurements of the rates of transport of both pollutants and organic matter through major parts of a system;
- (2) A breakdown of this picture into smaller components such as trophic levels, or, when required, particular species;
- (3) An investigation of the homeostatic or controlling factors which maintain the system in the face of environmental fluctuations.

The first stage would be concerned with the estimate of the fluxes of pollutants through the sea surface, their rates of incorporation in plankton in the euphotic zone, the fallout from this zone into deeper water, and the processes in sea-bed. At the same time the fluxes of radiant energy in the sea and the consequent rates of photosynthesis and changes in organic matter would be measured. In the second stage a more detailed partition in each of the processes would be attempted. Both these stages when combined with the types of experiments described above will increase the capability to evaluate the effects of pollutants. The third stage is to be able to describe not only what is in the environment and the rates of change involved but to get some understanding of the factors determining these quantities, their rates of change and hence of the influence of pollutants as extra perturbations.

In this progress the information required about the physical or chemical environment becomes more important and more exacting in terms of choice of areas, design of observations and measurements of details of local advection and diffusion, so that a close integration of disciplines is required.

Also in this progress the methods of linking and synthesizing observation and experiment increase in significance. Initially we are concerned to provide a box model, later to study varying rates of change and lastly to set up a simulation in which the control mechanisms are explicitly defined on the basis of experiments and tested against observation. It is the eventual aim that experimental results on the effects of existing or new pollutants can be combined with such models to provide predictions of some major effects, with indications of where these effects may occur in a food web and what their magnitude may be.

It has been deemed necessary to go into this detail on the possible pattern by which research could develop since only in this way can we define the size or nature of the problems facing us; the relative roles of observation, experiment and theory; but especially the need to integrate these aspects in single programmes. It is the nature of research that the rather sharp outline given here will change in shape and reveal different characteristics. The time scale is largely, although not wholly, a matter of investment. We have indicated that there are bases on which to build so that the first stages in observation and experiment are a matter of a few years. Simple homeostatic models already exist but the full programme is likely to take tens of years. The chances for success in the predictions cannot themselves be predicted but the step-by-step approach outlined has the potential of continual improvement in its degree of realism. Lastly, the long-term nature of such investigations will, of necessity, generate long-term series of observations which should link with previous and future programmes to measure distribution and trends in biological parameters and levels of pollution.

If we are to mount such penetrating investigations then the sites chosen will be crucial. The present need to study certain areas already of concern - the North, Baltic and Mediterranean Seas - suggests that at least one of the sites be in these areas. But the long-term nature of the problem and the possible threats posed by changes and by expansion in many countries imply that we must also start now to think of comparable investigations in other areas. We are going to be faced with questions of the effects in the open ocean and must consider how best this can be tackled. It may be that oceanic islands which have proved very useful as bases for research in deep water can be used in our context.

Yet the most significant need for forward planning concerns work in tropical regions. A major difference between tropical and temperate (or arctic) regions is the very much greater diversity of species in the former. There have in the past been suggestions that such diversity was related to stability which would include the ability to withstand environmental perturbation. It seems more likely now that the opposite is true and that many tropical areas, perhaps because their physical environment is relatively stable, are unable to absorb perturbations, especially those resulting from man's activities. Thus again as a hypothesis, it is possible that areas of relatively open sea in the tropics or sub-tropics may be more sensitive to pollution than temperate regions. For this reason we must consider very urgently the need for comparable investigations in the former areas organized as cooperative studies with the investigations proposed for high latitudes. Such regional comparison will provide a valuable critical check on the generality of the results obtained in each and should link closely with the interpretation of data from global monitoring.

